DWR OROVILLE FACILITIES RELICENSING PROJECT
(FERC Project No. 2100)

STUDY #1C: OROVILLE RESERVOIR TEMPERATURE MODEL DEVELOPMENT

December 12, 2001

1.0 INTRODUCTION/BACKGROUND

The Oroville Reservoir operations play a significant role in controlling the temperatures downstream on the Feather River. The release from Oroville Reservoir and their temperatures are critical in meeting the often conflicting temperature requirements for downstream fishery purposes and agricultural diversions. There is a temperature control structure on the existing reservoir inlet that works to allow control of release temperatures and management of the cold water pool in Oroville Reservoir. Evaluation of alternative reservoir operations impacts on release temperatures requires development of an Oroville Reservoir temperature model.

2.0 STUDY GOAL(S) AND OBJECTIVE(S)

The goal of this study is to develop a temperature model for Oroville Reservoir that can simulate release temperature under different operational alternatives and benchmark simualtions. Simulation of the spatial temperature distribution within Oroville Reservoir or of other water quality constituents such as DO and pH are not considered in the model development process. Initial co-ordination efforts have indicated that these issues are not of concern at this time.

If these issues become of concern later in the process the model developed under this study plan may not be appropriate for use and additional model development may be required.

3.0 RELATIONSHIP OF THE STUDY PLAN TO RELICENSING PROJECT PROCESS/PURPOSE AND NEED FOR THE STUDY

Relationship of the Study Plan to Relicensing Project Process.

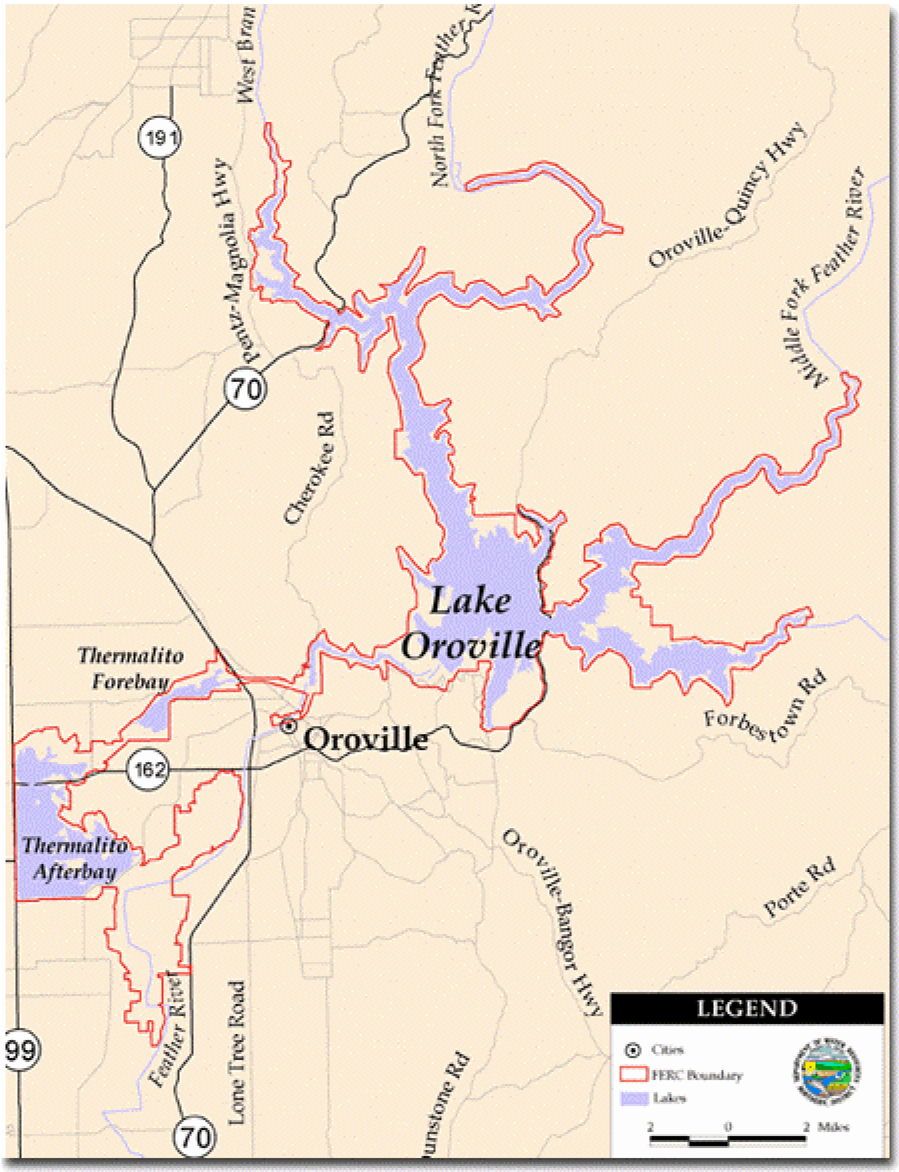
In order for the Oroville facilities to obtain a new license the Federal Energy Regulatory Commission (FERC) requires water quality certification from the State Water Quality Control Board (SWRCB). The certification requires that SWRCB determine that the project complies with the temperature requirements of the Central Valley Water Resource Control Board (CVWRCB) Basin Plan (SPW1, 01).

Purpose and Need for the Study

There is a need for the development of a temperature model for the Oroville Reservoir to allow simulation of release temperature for use in other study plans and as input to other modeling efforts.

4.0 SCOPE – STUDY AREA

The study area includes Oroville Reservoir including inflows and releases.



5.0 GENERAL APPROACH

This study will evaluate potential models and tools that could be used to develop a temperature model of Oroville Reservoir. The resulting model will be capable of simulating the release temperatures under various operational alternatives.

Task 1 – Determine model capability requirements

- Evaluate study plans and potential data requests from other work groups and/or regulatory agencies to determine desired model outputs
- Decide on the model complexity needed for the study. Due to the length of the reservoir, a 1-D model may or may not be of adequate complexity to perform simulations. A 2-D or 3-D model may be necessary to generate appropriate release temperatures.
- Evaluate the impacts of pumpback operation on temperatures in Oroville Reservoir to see if they need to be considered in the modeling. Implementation of this feature into the Reservoir model may require modifications to the selected modeling tool. This will use the results of Study Plan No. – 8: Temperature Impacts of Pumpback Operations at Oroville Reservoir.
- Evaluate the need for "real time" versus "seasonal" temperature operations at Oroville Reservoir. "Real time" operation where the temperatures are managed only for the present and near future needs is different than "seasonal" operations where availability of cold water for temperature control in other times of the year are important. This difference could require modifications to the modeling tool or development of addition tools to implement the seasonal temperature operational goals. This will use the results of Study Plan No. – 7: Oroville reservoir Cold Water Pool Analysis.

Task 2 – Gather and Evaluate Existing data

Typical Data needed for Reservoir Temperature Modeling

The following are typical parameters needed for reservoir temperature modeling:

- Reservoir inflow, outflow
- Reservoir outlet configuration
- Stratification data
- Storage-area curve
- Storage-elevation curve
- Target temperature
- Inflow temperatures
- Air temperatures
- Evaporation
- Solar radiation
- Air temperature coefficient
- Inflow mixing coefficient
- Vertical diffusion coefficient
- Evaporation coefficient
- Insolation coefficient
- Equilibrium temperature
- Heat exchange coefficient
    - Air temperature

- Solar radiation
- Relative humidity
- Wind speed
- Cloud cover
- Solar altitude
- Solar reflectivity

Existing Data

- State Water Projects Operations data for Oroville Reservoir
  - Water Surface elevation (ft)
  - Storage (ac-ft, daily)
  - Storage change (ac-ft, daily)
  - Outflows
    - Hyatt Powerplant
    - Palermo Canal
    - Evaporation
    - Spill
    - Total outflow
  - Inflows
    - Hyatt Powerplant pumpback
    - Computed inflow
  - Temperature Oroville-Thermalito Complex (deg F)
    - Mean daily water temperature, Afterbay outlet
    - Mean daily water temperature, fish hatchery
    - Oroville Reservoir temperature profile, graph of temp by elevation (Fahrenheit/ft), profile taken near the intake
- California Data Exchange Center at Oroville Dam
  - Precipitation, accumulated (inches, hourly)
  - Precipitation, incremental (inches, daily)
  - Storage (af, daily, hourly and monthly)
  - Reservoir elevation (feet, daily and hourly)
  - Reservoir scheduled release (cfs)
  - Full natural flow (cfs)
  - Storage change (af, daily)
  - Reservoir outflow (daily, hourly)
  - Evaporation (af, daily)
  - Reservoir inflow (cfs, daily, hourly)
  - Discharge, control regulating (cfs, hourly)
  - Reservoir, top conserve storage (af, daily)
- UC IPM Weather database:
  - Station
  - Date
  - Obs. Time
  - Precip
  - Temp (max, min, observed)

- Weather conditions
- Wind (direction and speed)
- Bulb temperature (wet, dry)
- Soil temperature (max, min)
- Pan evaporation
- Solar radiation
- Reference evapotranspiration
- Rel. humidity (min, max)

Task 3 – Identify existing modeling tools and/or models

This task will research existing models and or modeling tools that could be used study plan. Currently identified models include:

Existing Models of Oroville Reservoir

USBR Temperature Model (Rowell, 1990)

The model simulates one-dimensional, vertical distribution of Oroville Reservoir water temperature using monthly input data on initial storage and temperature conditions, inflow, outflow, evaporation, precipitation, radiation and average air temperature. It also has been integrated with a river temperature model (FEATEMP) for downstream predictions on the lower Feather River. The USBR monthly temperature model (HEC) is used in conjunction with PROSIM, a reservoir operations model, to develop relationships between upstream reservoir impacts from Oroville Reservoir on downstream river temperature.

HEC-5Q (USACE-HEC 1987c), (Deas and Lowney, 2001)

The Corps of Engineers developed a daily time step model of the Sacramento River Basin, including the Feather River using the HEC-5Q modeling tool. The model was used for instructional purposes by the Corp in preparation of their Training Document 24. The Hec-5Q modeling tool used simulates a one-dimensional, vertical temperature distribution for reservoirs; and a one-dimensional, longitudinal distribution for rivers. Reservoir-river simulations can be processed in a single run and includes comprehensive operations logic to accommodate operations (e.g. flood control, hydropower production)

Examples of Other Modeling Tools

- **WQRRS** (USACE-HEC 1986), (Deas and Lowney, 2001)
    - Model was used on the North Fork of the Stanislaus River (Smith, 1981), and Shasta and Trinity reservoirs (Orlob et al. 1993) and Meyer and Orlob, 1994) to develop relationships between upstream reservoirs and downstream river temperature effects.
    - Developed by the ACE
    - Can also be used as a reservoir and river temperature model
    - Reservoir-river simulations must be processed separately

- One-dimensional, vertical temperature distribution for reservoirs; one-dimensional, longitudinal distribution for rivers.
- Hourly timestep
- Includes broad range of water quality and ecological processes

- **RMA** (Deas and Lowney, 2001)
  - Versions 2 and 11 predict flow and temperature, respectively
  - This model generates hourly predictions
  - Both versions are one-dimensional
  - They model both reservoirs and streams
  - They have been applied to the Sacramento and Feather rivers, and Keswick reservoir (Deas et al., 1997, Jensen et al., 1999)

- **BETTER** (TVA, 1990), (Deas and Lowney, 2001)
  - This model generates daily predictions
  - It predicts temperatures in reservoirs both vertically and longitudinally
  - It models water quality in reservoirs only
  - It has been applied to the Lewiston and Whiskey Town reservoirs and releases to the Trinity River

- **CE-QUAL-W2** (Deas and Lowney, 2001)
  - Models reservoir water quality in two dimensions, vertically and longitudinally
  - Has been applied by Hanna, et al. (1999) to evaluate the effects of operations on temperature control device on reservoir thermal regime.

- **MIKE-11**
  - Simulates rivers and reservoirs
  - Dynamic, one dimensional
  - Consists of many modules for specific modeling simulations which can be run in conjunction or separately

Task 4 – Model Development, Calibration, Verification

This task is the actual development of the Oroville Reservoir Temperature Model.

Subtasks are:

- Select model/modeling tool for use
- Identify additional required data including type of data, quality of data and locations for collection. Specify monitoring needs including instrumentation and data collection processes required to obtain the data.
- Begin model development with existing data. Use assumed values for additional required data until it is collected.
- Perform model modifications, if required, for pumpback operations

- Calibrate/verify the model
- Develop “seasonal” operation tools or model modifications if required

The calibration/verification process will likely be the longest process involved in the study plan.

Task 5 – Perform Initial Benchmark Oroville Release Temperature Analysis as required

Using the developed model perform the Oroville Release Temperature simulations required for the initial 2001 and 2020 Benchmark Studies.

6.0 RESULTS AND PRODUCTS/DELIVERABLES

Results

This study plan will result in a temperature model capable of simulating temperatures for various operating scenarios in the Oroville Reservoir. It will output release temperatures from the dam that will be utilized for impact analysis and/or as input to other modeling efforts.

Products/Deliverables

There will be two products from this study plan:

1. An Oroville Reservoir temperature model that can simulate release temperatures. The model will include pumpback impacts if required and will be capable of modeling both real time and seasonal temperature operation constraints for cold water pool management. The model will be fully integrated into the overall modeling scheme.
2. Simulated Oroville temperature and release temperature data for the 2001 and 2020 benchmark studies for use in other analysis.

7.0 STUDY PLAN COORDINATION AND IMPLEMENTATION STRATEGY

Coordination with Other Resource Areas/Studies

This study will be coordinated with a number of other Engineering and Operation study plans:

Study Plan No. 1 - Model Development
Study Plan No. 1b - Local Operations Model Development
Study Plan No. 1d - Thermalito Complex Temperature Model Development
Study Plan No. 1e - Feather River Temperature Model Development
Study Plan No. 2 - Modeling Simulation
Study Plan No. 7 - Oroville Reservoir Cold Water Pool Analysis
Study Plan No. 8 - Temperature Impacts of Pumpback Operations at Oroville Reservoir

The development will also be coordinated with study plans from other workgroups that will require evaluation of temperature impacts on Oroville releases.

Related Study Plans: SPW1, SPW4, SPW6
Related Issues: W1-W3, W9-W14, W16

Study Plan Tracking/Regulatory Compliance Requirements

In order for the Oroville facilities to obtain a new license the Federal Energy Regulatory Commission (FERC) requires water quality certification from the State Water Quality Control Board (SWRCB). The certification requires that SWRCB determine that the project complies with the temperature requirements of the Central Valley Water Resource Control Board (CVWRCB) Basin Plan (SPW1, 01).

8.0 REFERENCES

Deas M.L. and C.L. Lowney, 2001. Bay Delta modeling forum water temperature modeling review Central Valley. BDMF Temperature Review DRAFT.

Deas M.L. and G.T. Orlob. 1997. Iterative calibration of hydrodynamic and water temperature models-application to the Sacramento River. *Proceedings Water for a Changing Global Community.* 27^{th} Congress of the International Association for Hydraulic Research and hosted by the American Society of Civil Engineers Water Resources Division, August 10-15, San Francisco, CA, 1997

Hanna, R.B., L. Saito, J.M. Bartholow, and J. Sandelin. 1999. Results of simulated temperature control device operations on in-reservoir and discharge water temperatures using CE-QUAL-W2. *North American Lake Management Society*. Vol. 15, No. 2. pp 87-102.

Jensen, M.X. Wang, J.J. Fellows, and G.T. Orlob. 1999. Temperature regulation through Whiskeytown Reservoir. Prepared for the US Bureau of Reclamation by the Water Resources and Environmental Modeling Group, Department of Civil and Environmental Engineering, University of California, Davis.

Rowell, J.H. 1990. *Mathematical model investigations: Trinity dam multilevel outlet evaluation – Trinity River temperature prediction study*. Trinity River Basin Fish and Wildlife Task Force; Interim Action Program. U.S. Bureau of Reclamation, Sacramento, CA.

(SPW1, 01) Water Quality Study Plan 1.

Tennessee Valley Authority (TVA). 1990. *BETTER: A two-dimensional reservoir water quality model, technical reference manual and user's guide.* Water Resources Research Laboratory, Report No. WR28-2-590-152. TN.

United States Army Corp of Engineers – Hydrologic Engineering Center (USACE-HEC). 1986. *WQRRS Water Quality for River Reservoir Systems, User's Manual.* Hydrologic Engineering Center. October, 1978, revised 1986.

United States Army Corp of Engineers – Hydrologic Engineering Center (USACE-HEC) 1987c. *Simulation of flood control and conservation systems: appendix on water quality analysis.* September.